A Test of The Validity of the Elsberg Method of Olfactometry[1]

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In the Elsberg or blast-injection method of olfactometry, the absolute threshold is determined by finding the magnitude of blast of odorous air injected into the Ss' nostril or nostrils which will give rise to an odor sensation.[2] This is accomplished by the very simple device of releasing, through a pinchcock, odorous air which has been compressed by a known amount by means of a hypodermic syringe. Although the measurements so obtained are ordinarily expressed in terms of volumes, Jerome has shown that the effective variable is actually pressure.[3] The importance of pressure is further emphasized by Wenzel, although she further attempted to translate her stimulus magnitudes into number of odorous molecules in the blast.[4] Jerome's discovery that volume as such was not a variable would suggest, however, that the number of odorous molecules in the blast is not important so long as the concentration of odor is kept constant, as it always is in either the original Elsberg method or in Wenzel's adaptation of it.[5] We may conclude, on the basis of the above comments, that an Elsberg or blast-injection threshold has a meaning considerably different from a threshold obtained by changing the concentration of odorous molecules in the inspired or injected air. In fact, it becomes a matter of moment to decide whether or not the blast-injection threshold as ordinarily used is an olfactory threshold at all. That is, does the threshold depend upon the sensitivity of the receptors, or does it depend upon the aerodynamics of the nose?

The questions proposed in the preceding paragraph can be answered by varying the concentration of odor in the injected air, and determining the effect thereof upon the blast-injection threshold. The reasoning here is that if the concentration of odorous molecules, or their number in the blast, is of importance in determining the blast-injection threshold, then blasts of different magnitude should be necessary to reach threshold with odors of different concentration. For example, if one bottle contains air saturated with a given odor, and another contains air with only one-third the saturated concentration, then a proportionally larger blast of the less concentrated air should be required to reach threshold. If, on the other hand, the aerodynamics of the nose is the determining factor, and it is further assumed that the weaker concentration is above threshold olfactorily, then the concentration should have no effect. Needless to say, we may also encounter various intermediate possibilities, in which the obtained blast-injection threshold is a function of both variables, plus, perhaps, still others. The experiment reported here attempts to decide the issue presented above.

Apparatus and Procedure

The design of the six stimulators followed essentially the Elsberg pattern.[6] Since Jerome's work showed that the volume of the container was of importance only insofar as it affected the pressure obtained from a given volumetric compression, no attempt was made to duplicate the Elsberg bottles exactly. The bottles used in the present study had a capacity of about 250 ml, and were as alike as modern mass-production methods could make them. Each was provided with a rubber stopper through which two glass tubes were inserted. One of these tubes was attached during experimentation to the hypodermic syringe used for compressing the contents, and extended to within about 2 cm of the odorous liquid within the bottle. The exit tube, attached, when the bottle was in use, to the nose-piece, extended only a millimeter or two into the bottle. The stoppers were carefully covered with aluminum foil, and the connection of tube to syringe and tube to nose-piece was effected with silicone rubber tubing.[7] Hence, there was absolutely no odorous foreign material at any point in the system.

The odorous material in all cases equaled 20 ml in volume. In order to obtain different concentrations of odor, advantage was taken of the fact that in solution the vapor pressure of a substance is an inverse ratio to its molecular concentration. The solvent used was heavy mineral oil, USP, which is odorless and with which the two odorous substances used are completely miscible. The odorous substances were n-octane, obtained from the Eastman Kodak Company, and amyl acetate, obtained from the Mefford Chemical Company. Three concentrations of each were prepared as follows: (1) pure; (2) half odor and half mineral oil; (3) one part odor to nine parts mineral oil. If we assume the molecular weight of the mineral oil to be 414, and further assume ideal conditions, we should expect the concentrations of each odor to be available, therefore, first, at the level determined by the vapor pressure of the substance; second, at a level of 76% of the pure substance in the case of amyl acetate, and 74% for octane; and, third, at a level of 26% of the concentrated level for amyl acetate and 24% for octane. When the unstoppered bottles were sniffed, the differences in concentration were clearly evident, as would be expected from the approximate RL for odor.[8] The n-octane was very much weaker in odor than the amyl acetate.

For reasons of simplicity, it was decided to use monorhinal stimulation. Hence, single nose-pieces were constructed for each odor which consisted of a straight tube, 3 mm in inside diameter, sealed through a flaring tube which served to close off the nostril. In order to keep the jet as constant as possible, the same nose-piece was used for each level of a given odor, but was purged with air at the level of concentration each time the bottles were changed. The varying degrees of compression were obtained with a standard 50 ml hypodermic syringe. All experimentation was done in the same room, which was located in the basement, without outside opening, and which was kept at a relatively constant temperature by a thermostatically controlled flow of washed air from the central ventilating system. There was never more than a 1/2 degree Fahrenheit change during any one session (each session required about 40 minutes), nor more than a one degree change from one day to the next.

In all, 10 Ss were used, including the experimenter, who was tested by NHJ. Except for E, the design and purpose of the experiment were known to none of the Ss, and, since E's results appear to be of the same order as those for the other Ss, they have been retained in the calculations. The other 9 Ss were staff members and graduate students in the Department of Psychology. None was experienced in olfactory work, but no difficulty in making the required judgments was encountered by any of them. Each was used during only one relatively brief session, so problems of diurnal and day to day variation were not involved.

Every S was tested with every odor at one sitting. In order to minimize systematic effects, several different orders of presentation were used for the different Ss, followed immediately by the same order in reverse (a "balanced order," in other words). The one limitation placed upon the orders was that all three levels of the same substance were always given in succession, although, of course, sometimes starting with the lowest concentration, sometimes with the highest. This arrangement had the advantage of simplicity in manipulation of the apparatus, and inspection of the data reveals no particular trend or systematic bias. Each threshold reported in the results thus represents two measurements for each S on each odor. This was deemed sufficient for two reasons, first, the variability of results was far less than the expected variation from level to level if the technique were an actual test of odor threshold, and, second, it was desired not to fatigue the Ss. As is standard practice with the blast injection method, all thresholds were obtained by an ascending series, and each blast exceeded the previous one by 1/2 ml. It should be emphasized that the utmost care is required for S not to breathe during or immediately after a blast. Fortunately, S can almost always distinguish between an immediate odor, and one arising after a breathing movement.

Results

The results are summarized in Table I. In keeping with the usual practice, thresholds are given in terms of ml. of blast, rather than in terms of pressure. An approximate translation to pressure would place the thresholds at 5 to 7 mm. of Hg, which is of the same order of magnitude as the thresholds obtained by Jerome for a different substance, and with birhinal stimulation. In order to check on the statistical significance of the differences obtained, t was calculated for the largest difference, that between 100% and 50% n-octane, using a distribution of actual differences. This *t* was only 0.73, which is not at all significant, and so no others were calculated. It is true, of course, that if a very large number of Ss were used, a difference of the magnitude found would be statistically significant. However, the differences are small compared to those which would be predicted on an "equal molecule" basis, and the trend from more to less saturated is not consistent.

Discussion

It would appear from the results cited above that thresholds obtained by use of the Elsberg or blast-injection technique are not understandable in terms of molecular concentration. Over a range of concentrations the obtained thresholds are independent of the concentration of odor in the injected air, which would preclude any translation into molar or similar terms referring to molecules per unit volume. If the blast injection thresholds are not true olfactory thresholds in the usual, that is, molecular concentration sense of the term, then we must look for some other way in which to understand the effect of increasing pressure. This leads at once to considerations of the aerodynamics of the system. Since the situation is actually very complicated, it is possible here only to outline the general problem.[9]

In the blast injection technique we are dealing basically with a jet flow phenomenon, modified by the size and conformation of the nasal cavity into which the jet is discharged. It is obvious, therefore, that the distance which the injected air will carry through the nasal passage, and the amount of mixing with the air already in the passage, will depend upon the pressure and duration of the blast, the size of the orifice in the nosepiece, the width and shape of the nasal passage, and, to a minor extent in this case, the density of the vapor.[10] In addition, the "pulse" would have to be taken into account, which further complicates matters. Considerable aerodynamical research, using models of the nose, would be necessary before the generalities stated above could be made more specific. Obviously, such a problem is of no direct interest in the present context.[11]

It would certainly seem to be good practice to utilize, in olfactory work, a technique which varies concentration rather than pressure. If one uses a blast of odorous material which is of sufficient pressure and volume to eliminate them as effective variables, and finds odor thresholds in terms of molecular concentration, the task of working out the relationships between stimulus effectiveness and physical and chemical characteristics of the odor is very much simplified. In the usual blast injection technique, unfortunately, one really does not know exactly what he is measuring, except that it is certainly not molecular concentration, and therefore he cannot compare his results with olfactory thresholds obtained by other methods.

Summary

1. Blast-injection olfactory thresholds were obtained for 10 Ss using three levels of concentration of each of two substances -- n-octane and amyl acetate.

2. No significant effect of concentration was found.

3. It was concluded that the blast-injection threshold is not comparable to thresholds found in terms of odor concentration, and is not translatable into molecular terms.

Table I

Absolute thresholds stated in milliliters for 10 Ss. Percentages refer to calculated vapor pressure percent of concentrated vapor.

	<u>n</u>-octane			amyl acetate		
	100%	76%	26%	100%	74%	24%
Mean (ml)	1.85	2.23	2.15	1.75	1.83	1.75
S. D.	0.64	0.59	0.68	0.54	0.88	0.80

Footnotes

1. This study was carried out as a part of contract N6onr-27515 with the Office of Naval Research.

2. C. A. Elsberg and I. Levy, The sense of smell. I. A new and simple method of quantitative olfactometry. Bull. Neurol. Inst. N.Y., 1935-36, 4, 5-19.

3. Cf. F. J. Hammer, The relation of odor, taste, and flicker-fusion thresholds to food intake. J. Comp. Physiol. Psychol., 1951, 44, 403-411; Franz R. Goetzl, M. S. Abel, and Ann J. Ahokas, Occurrence in normal individuals of diurnal variation in olfactory acuity. J. Appl. Physiol, 1950, 2, 553-562; and E. A. Jerome, Olfactory thresholds measured in terms of stimulus pressure and volume. Arch. Psychol., 1942, No. 274, pp. 44.

4. Bernice M. Wenzel, Differential sensitivity in olfaction. J. Exper. Psychol., 1949, 39, 129-143.

5. Jerome, op. cit., used citral floating on water; Wenzel, op. cit., used phenyl ethyl alcohol, the conditions making for a saturated vapor; Goetzl, op. cit., p. 554, used "ground coffee of a standard brand." In all cases. the odorous air would be at maximum saturation at a given temperature.

6. Elsberg and Levy, op. cit.

7. This tubing was obtained from the Connecticut Hard Rubber Company, New Haven, Connecticut.

8. Wenzel, op. cit., pp. 129-130, discusses the Weber fraction for odor.

9. Mr. Ernst R. Letsch of the College of Engineering at UCLA is attempting to analyze in aerodynamic terms the stimulus situation.

10. For 100% n-octane, the total mass of air has less than 6% octane vapor by weight. Thus, changing the weight by dilution has a very small effect.

11. If the dilution were carried further, there would probably be a point at which both concentration and pressure would affect the threshold, the limiting case being an odor which would be below threshold at any pressure. However, this is not relevant to the present discussion of the Elsberg technique as generally used.